

# MOUNTAIN PINE BEETLE-INDUCED CHANGES IN LODGEPOLE PINE NEEDLE FLAMMABILITY

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Mountain Pine Beetle Forum

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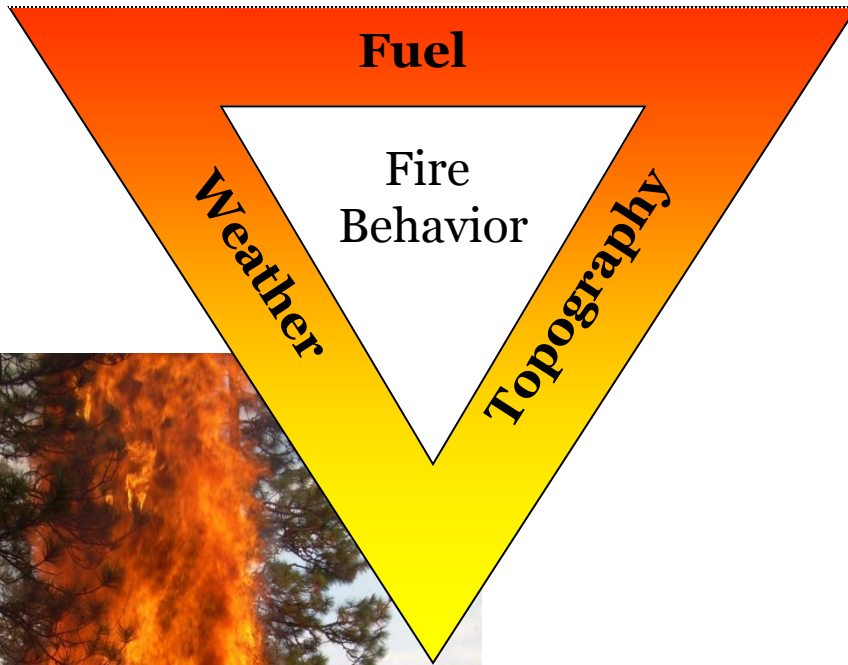


# OUTLINE

- Fire Behavior Primer
  - Important factors, types of fires and how they spread
- How beetles alter the fuel characteristics and potentially alter fire behavior
- What are we doing:
  - Examining fuel properties at various stages of attack
  - Testing the foliage flammability
  - Using measurements to simulate single tree fire behavior
- Take home points



# WHAT DRIVES WILDLAND FIRE BEHAVIOR?



## Fuel

- Amount
- Arrangement (Horizontal and Vertical)
- Chemistry
  - Moisture Content
  - Chemical make-up

## Weather

- Wind
- Solar radiation
- Temperature / Humidity

## Topography

- Steepness
- Orientation relative to the sun

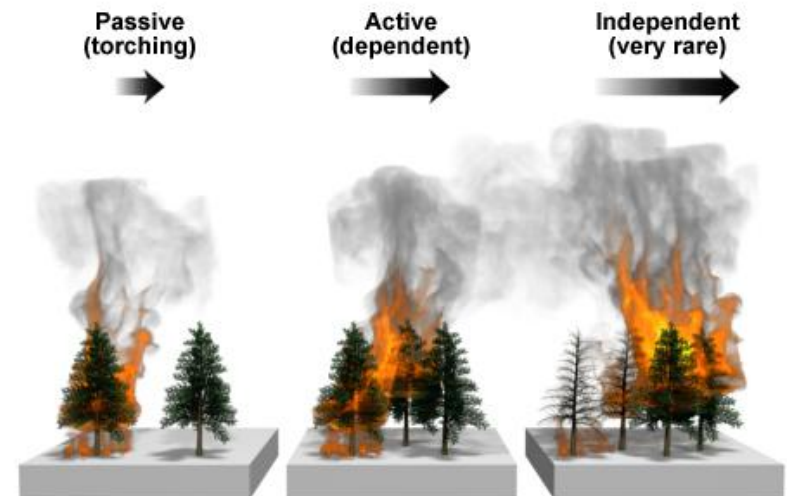


# TYPES OF FIRES

Fires burn in different strata of fuels:

- Ground fires
  - Organic matter
- Surface fires
  - Litter, logs, grasses, shrubs
- Crown fires
  - Burn in overstory trees
    - Passive (Torching)
    - Active (Dependent or independent of a surface fire)

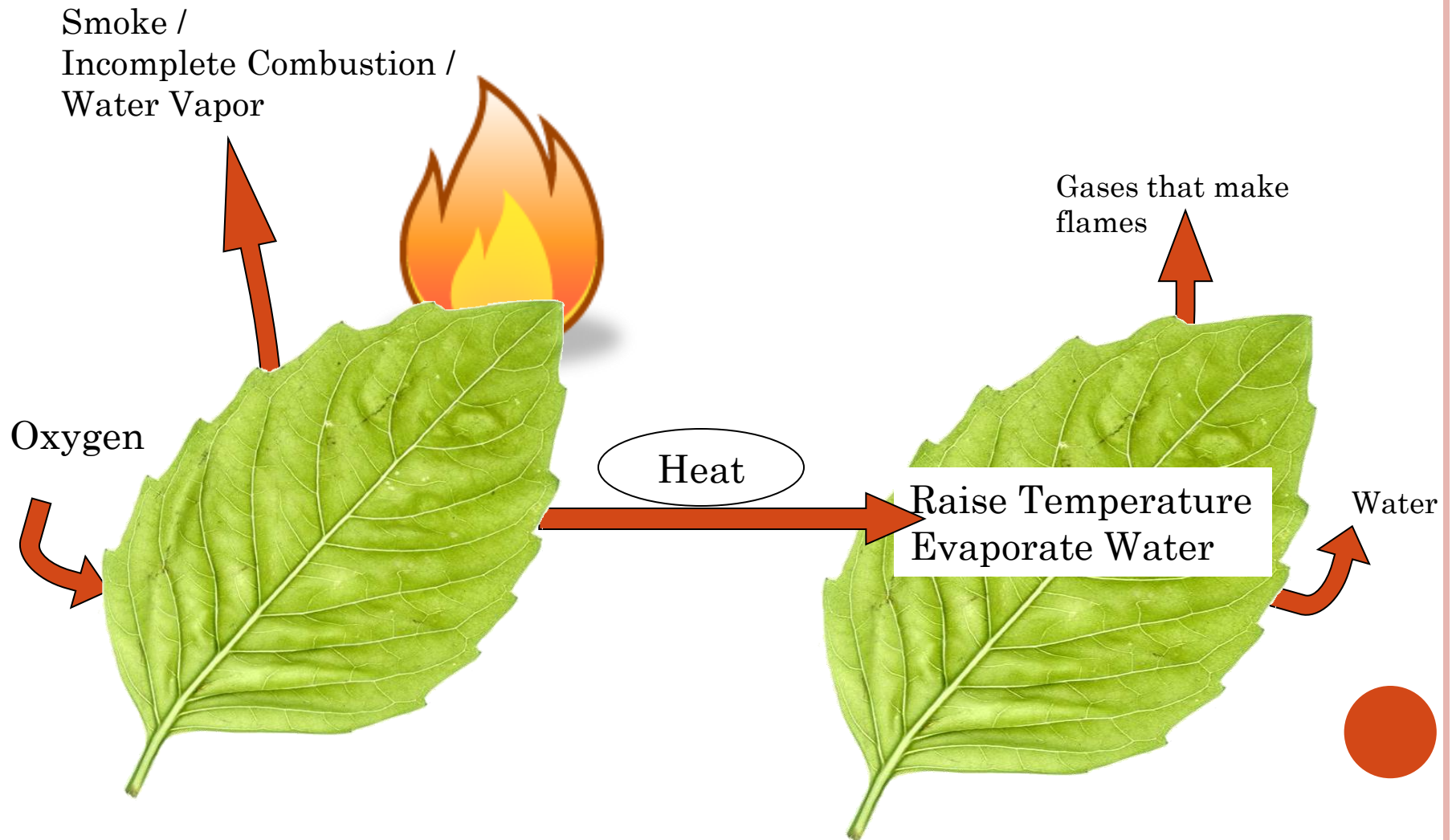
Stages of Crown Fire



NWCG/The COMET program



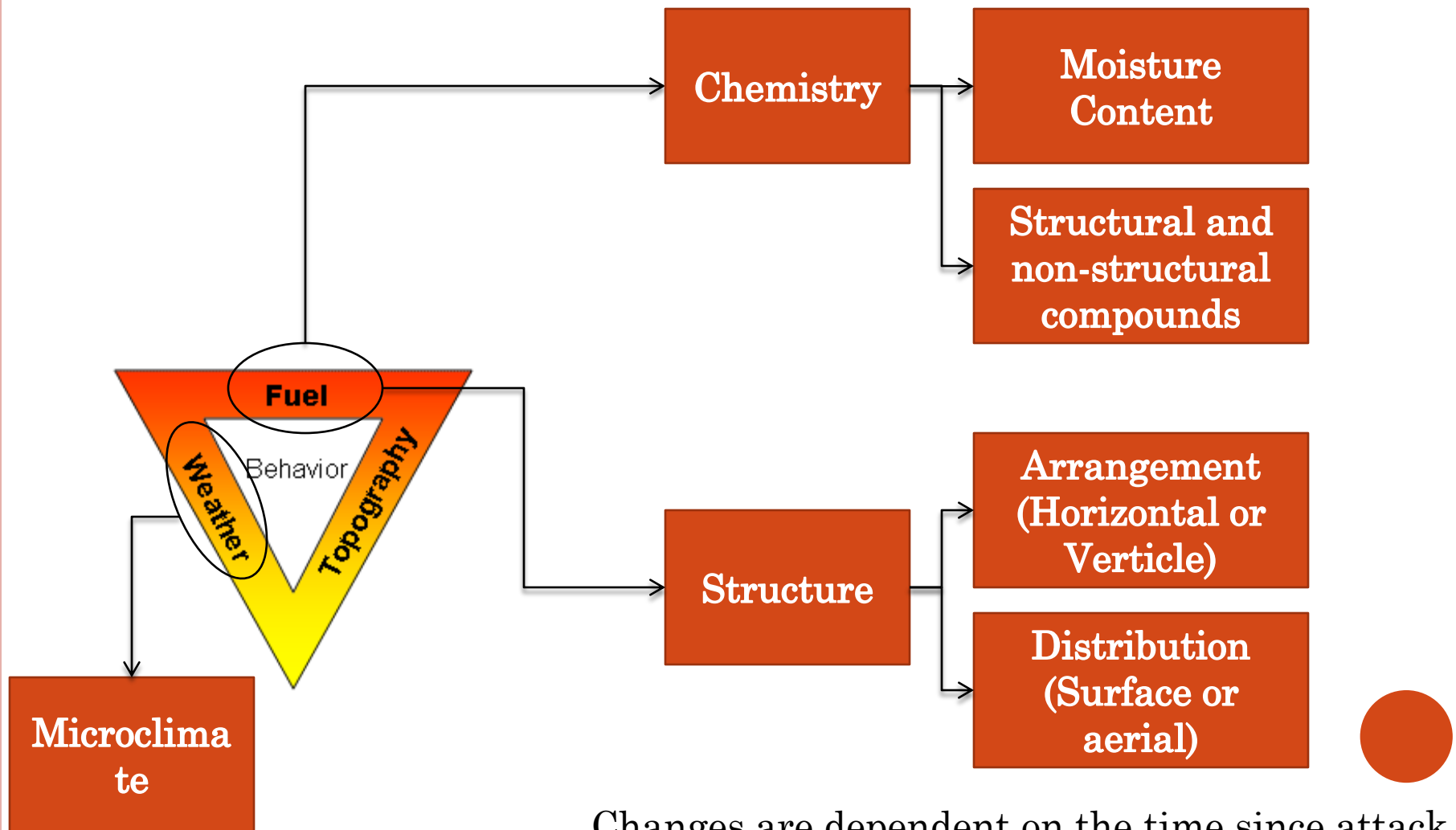
# HOW DO FIRES SPREAD?



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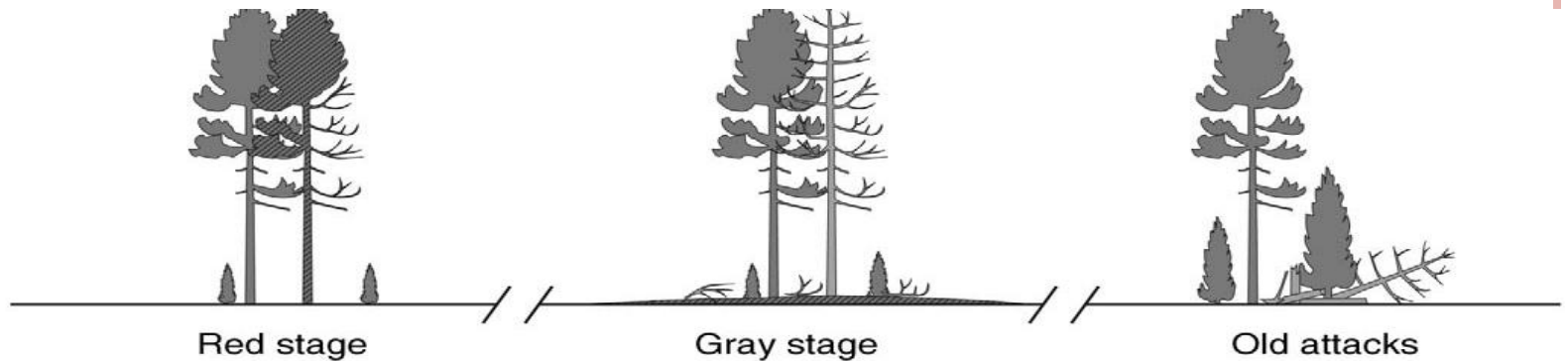
## **HOW DO MOUNTAIN PINE BEETLES WILDLAND FUELS?**

# HOW MOUNTAIN PINE BEETLES ALTER FIRE BEHAVIOR

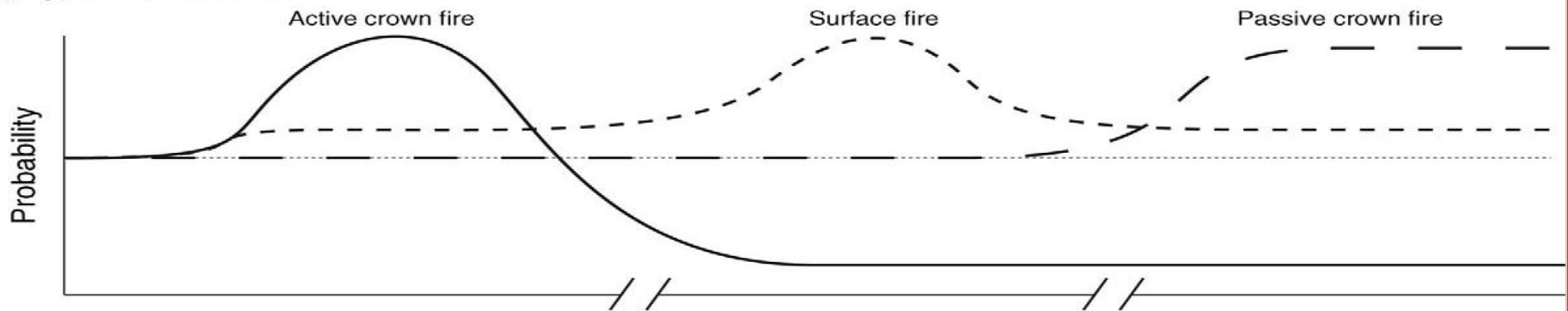


Changes are dependent on the time since attack

# HOW MIGHT FIRE BE EXPECTED TO CHANGE AFTER A MOUNTAIN PINE BEETLE ATTACK?



A) Hypothesized trends





# NEED FOR THIS WORK

- Context: Firefighters and the public are concerned with how fires are going to burn, not the longer-term, ecological perspective
- Current tools for predicting fire behavior are not valid in Mountain Pine Beetle-attacked trees
  - They were developed for healthy green trees
- New CFD-based fire behavior models are better suited for addressing these relationships between fuel alterations and fire behavior
  - We need good fuels information to feed these models to better understand how fires will burn in beetle-attacked stands



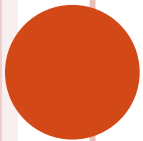
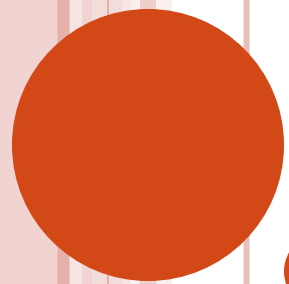
A decorative graphic on the left side of the slide. It features several vertical stripes in shades of light red and pink. Overlaid on these stripes are five solid orange circles of varying sizes, arranged in a cluster that tapers towards the bottom left.

# ASSESSING THE FLAMMABILITY OF BEETLE-KILLED TREES

# FUEL MOISTURE, CHEMISTRY AND IGNITION BEHAVIOR

- Starting before green-up in 2010 we selected trees in four distinct groups:
  - Healthy Green
  - Green Attacked
  - Transition (Yellow)
  - Red
- Sampled foliar moisture content, foliar chemistry and ignitability throughout the season





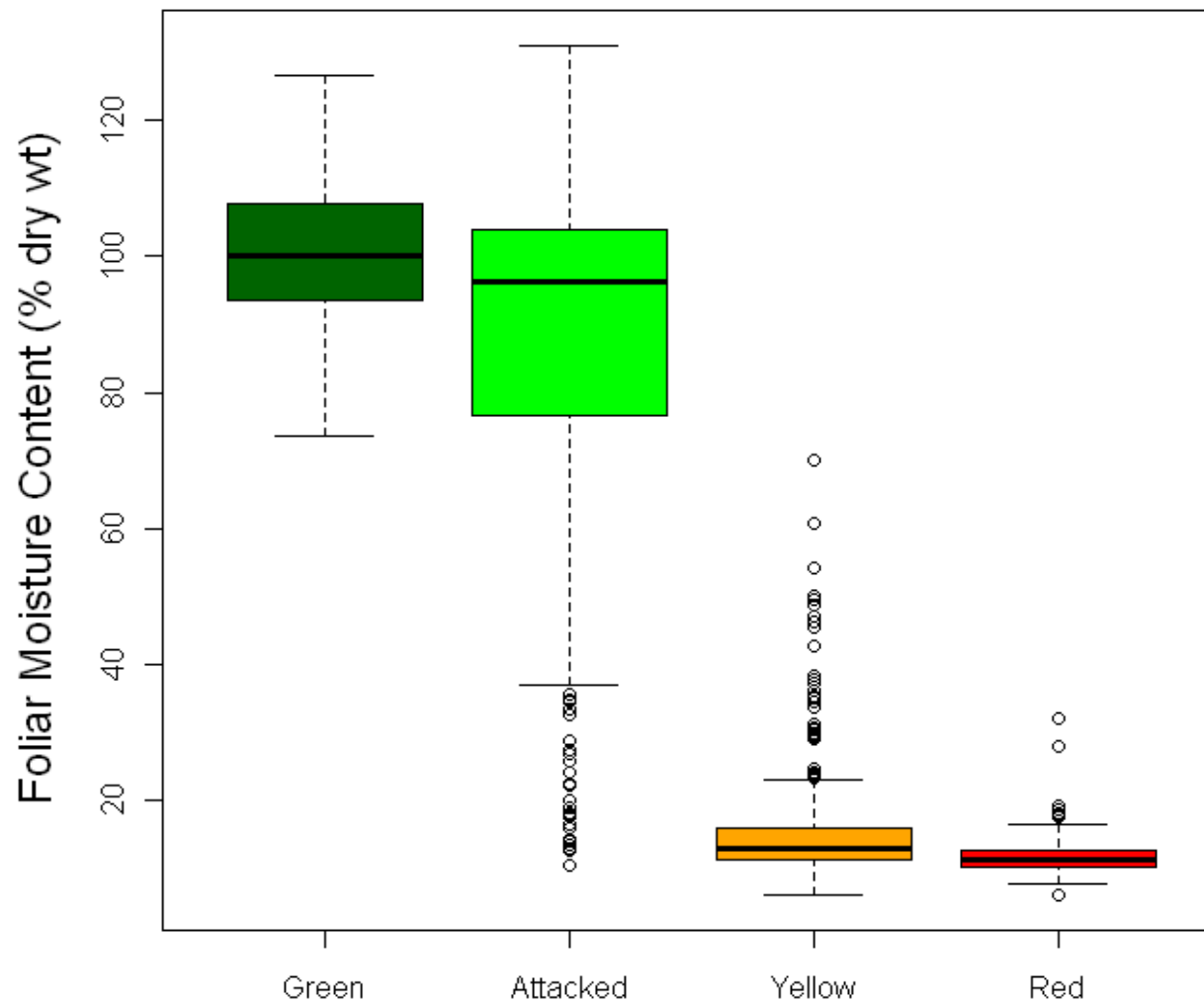
# FOLIAR MOISTURE CONTENT

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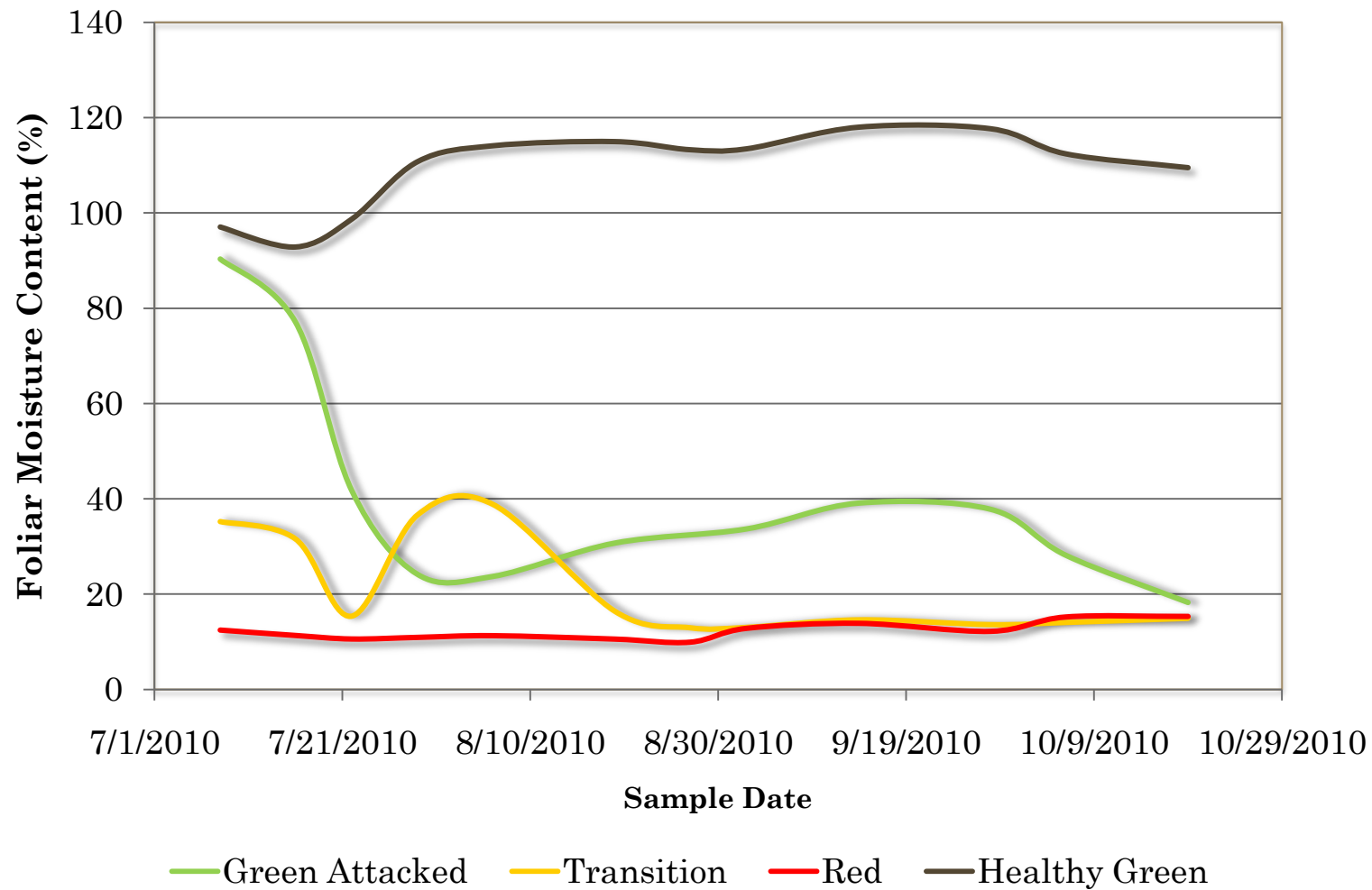
- Foliar moisture measured and expressed as a percentage of their dry weight
- Moisture content has long been considered an integral part of the ignition characteristics of fuels and has been shown to be an important factor in the ignition of healthy Lodgepole pine
  - Xanthopoulos, G. and Wakimoto, R. (1993). A time to ignition - temperature - moisture relationship for branches of three western conifers. Can. J. For. Res. 23(2): 253–258.



# AVERAGE FOLIAR MOISTURE CONTENT BY ATTACK CATEGORY

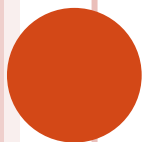
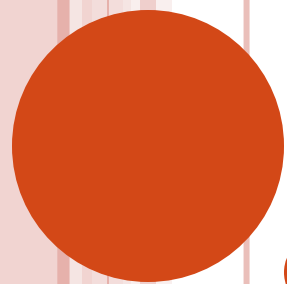


# FOLIAR MOISTURES OVER TIME BY CATEGORY



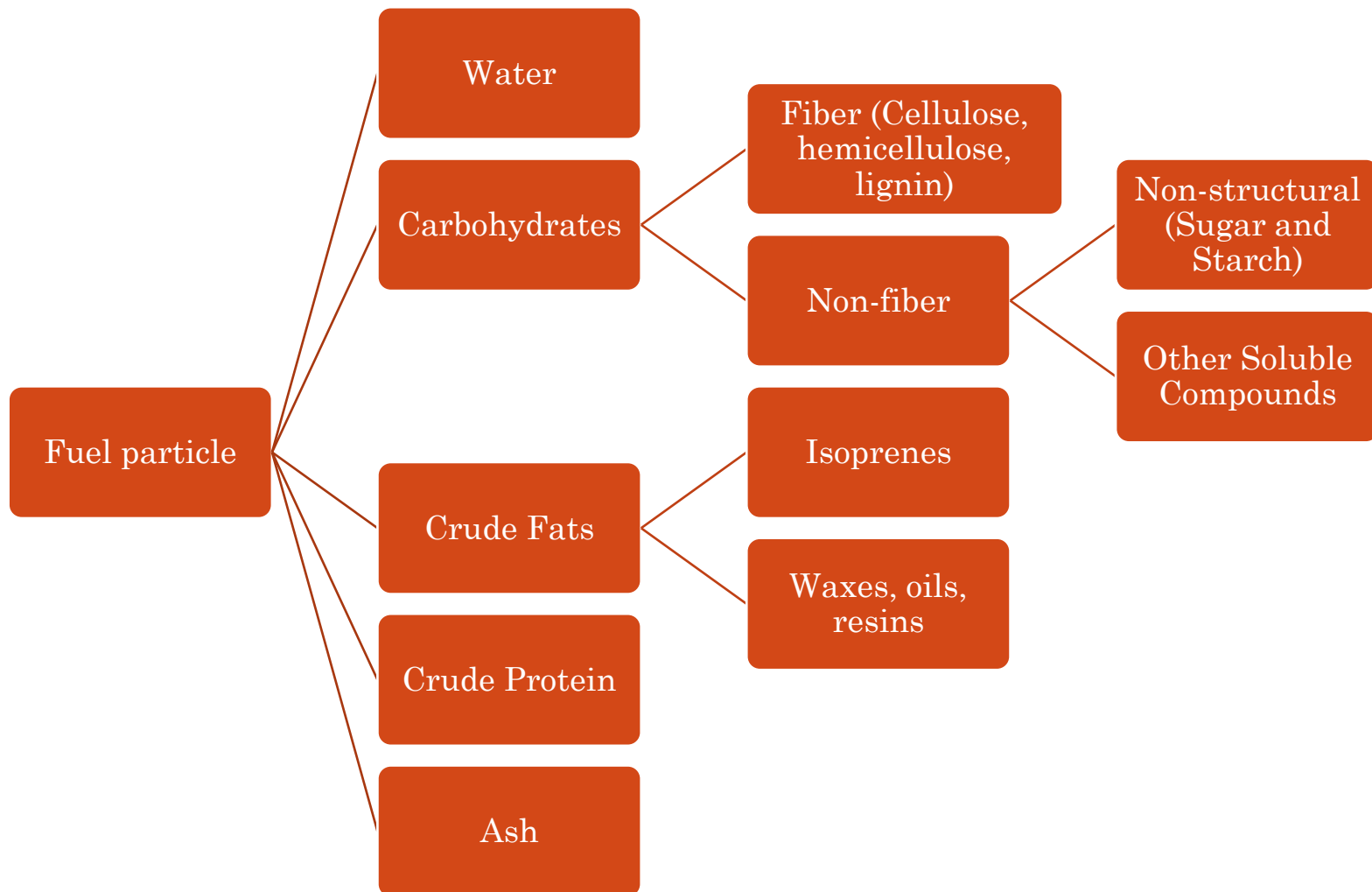
Tree Condition	Seasonal minimum FMC (% dry weight)	Seasonal maximum FMC (% dry weight)	Seasonal average and standard deviation FMC (% dry weight)
Green	81.0	120.3	100.7 (9.2)
Attacked	12.3	125.2	84.6 (30.9)
Yellow	8.4	59.3	16.1 (9.1)
Red	8.1	25.0	11.7 (2.3)



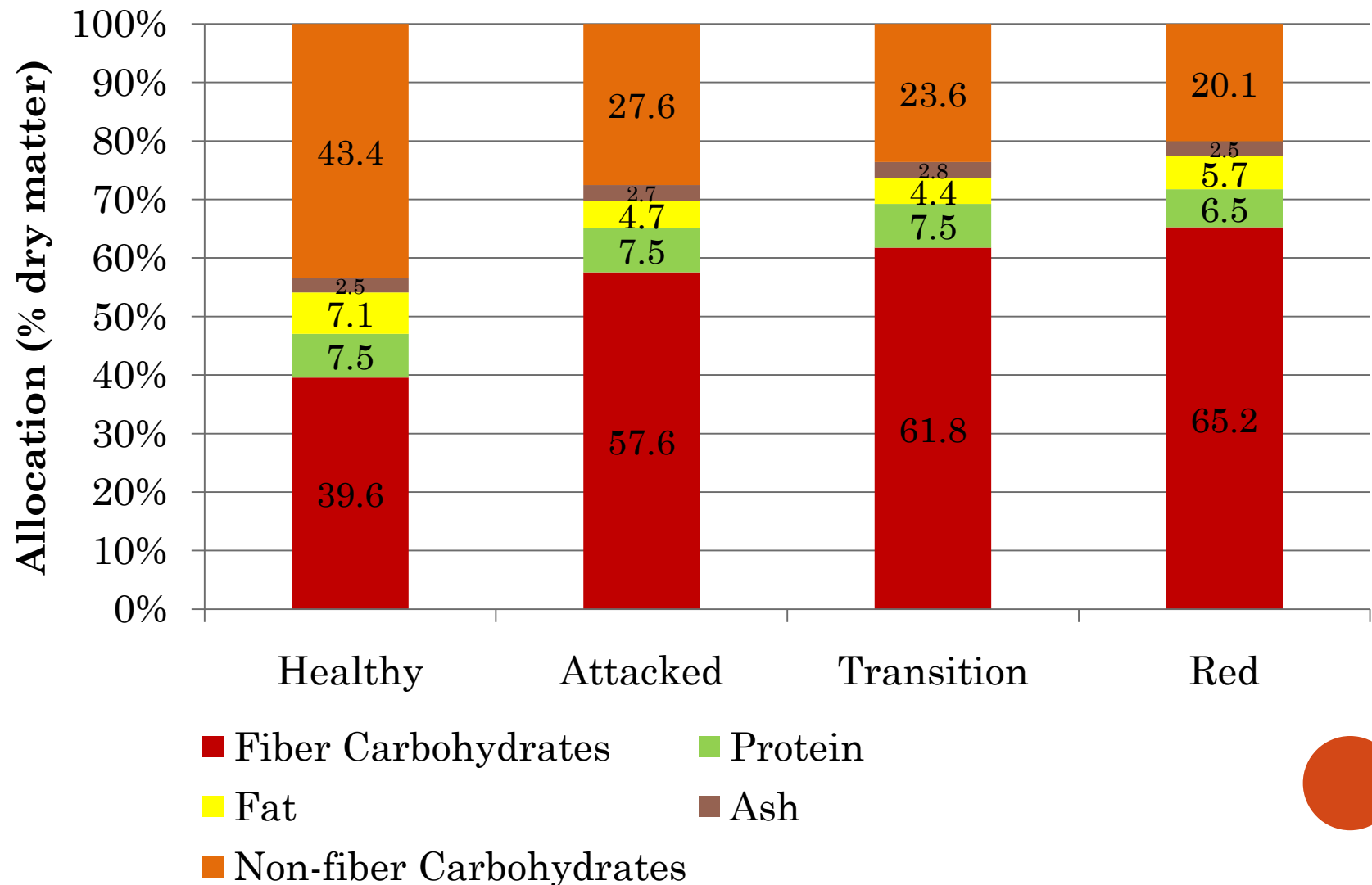


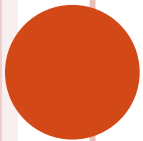
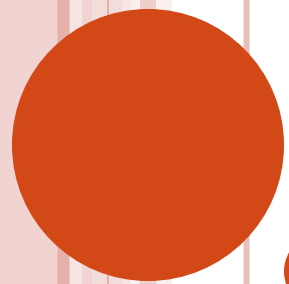
# FOLIAR CHEMISTRY

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# FOLIAR CHEMISTRY ACROSS THE FOUR STAGES OF ATTACK

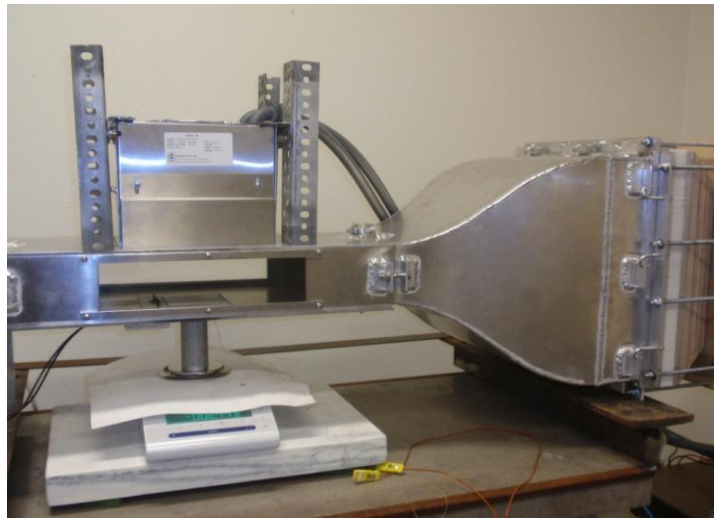




# FOLIAR FLAMMABILITY

# EXPERIMENT APPARATUS: SMALL-SCALE WIND TUNNEL WITH HIGH PRECISION BALANCE

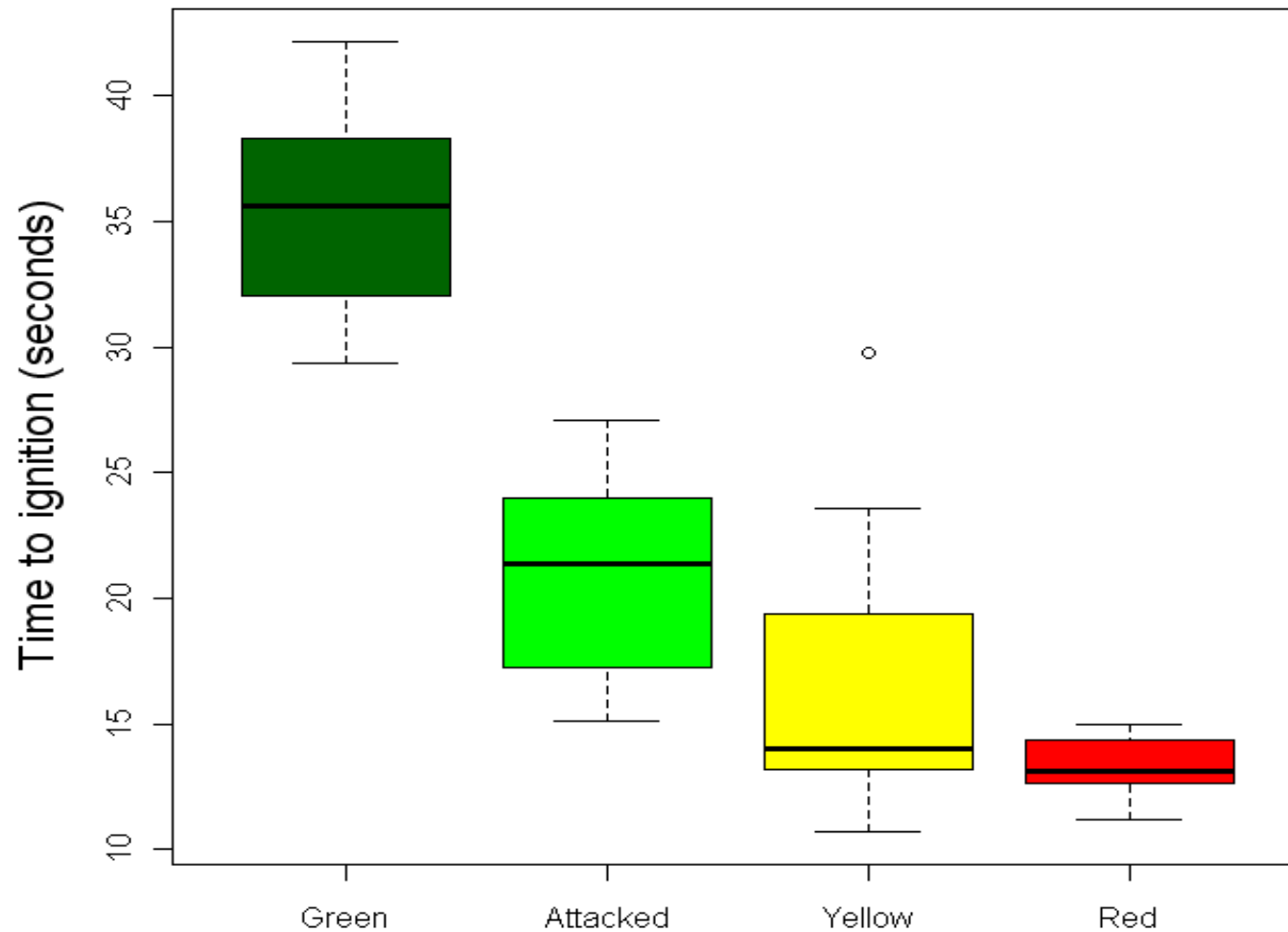
- Based on the Forced Ignition and Flamespread Test (Cordova *et al.*, 2001)



Thanks to Dr. Sara McAllister for use of equipment and for photos

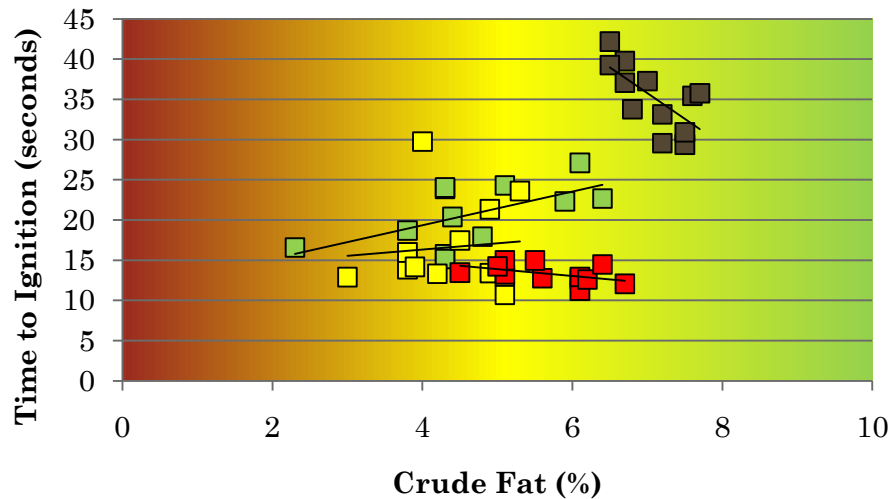
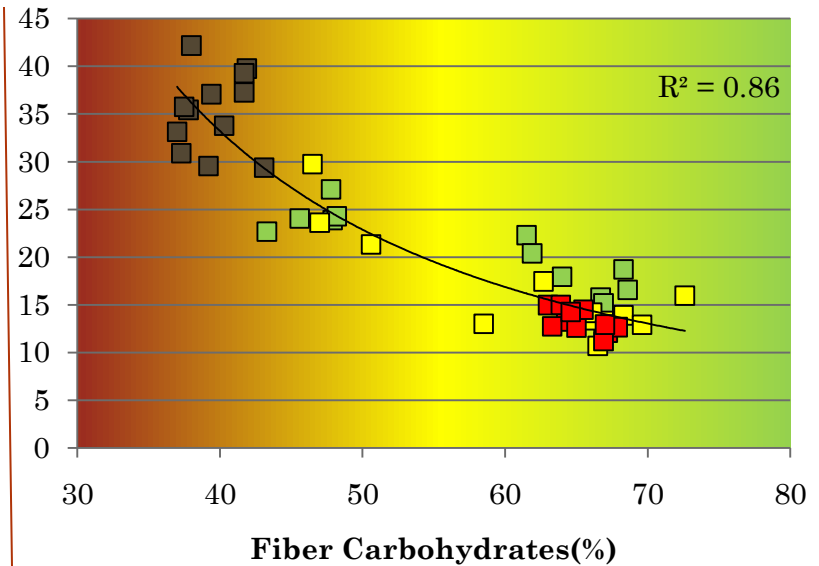
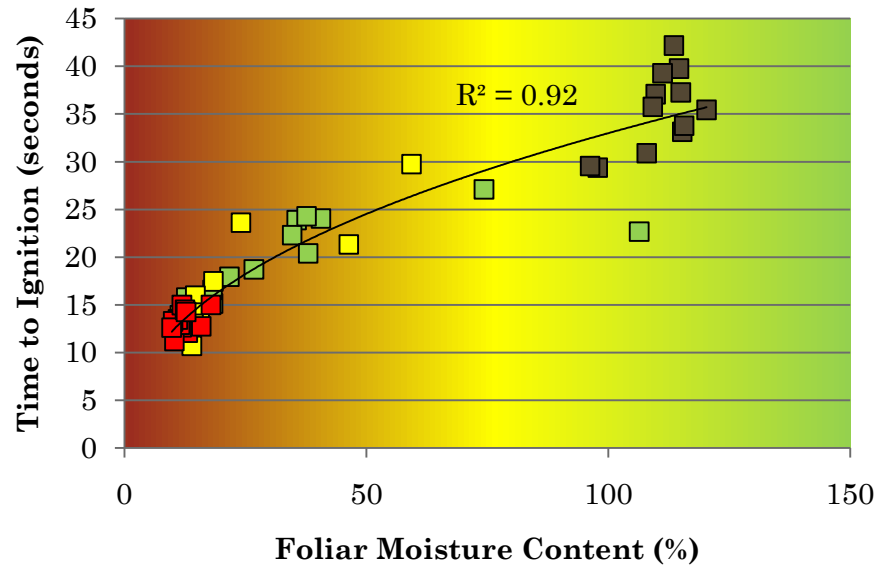
Cordova, J., Walther, D., Torero, J., Fernandez-Pello, A., 2001. Oxidizer flow effects on the flammability of solid combustibles. *Combustion Science and Technology* 164, 253-278.

# AVERAGE TIME TO IGNITION BY ATTACK CATEGORY



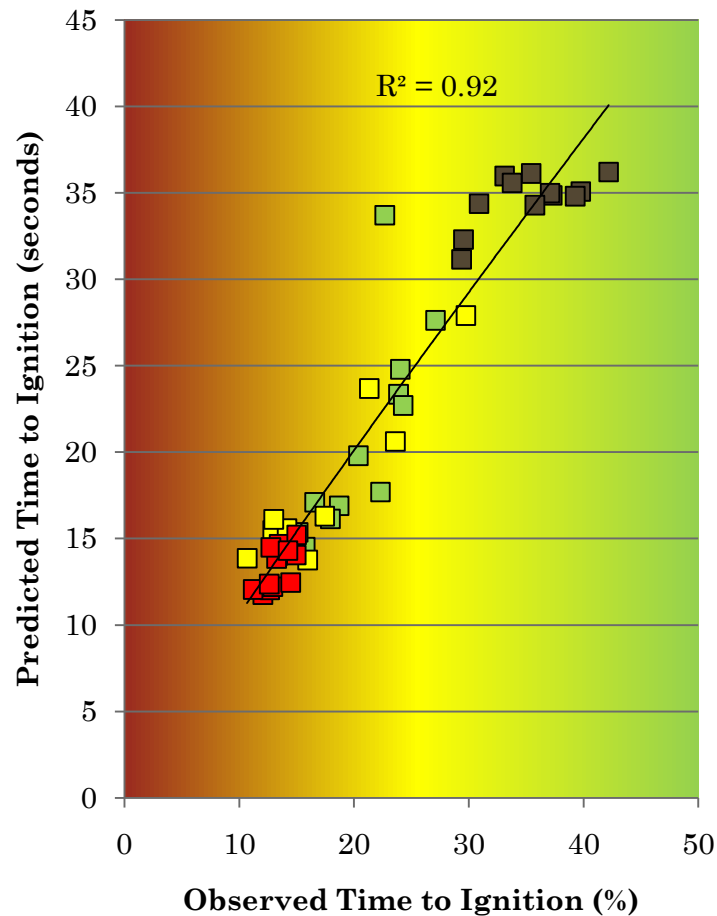
Tree Condition	Minimum time to ignition (seconds)	Maximum time to ignition (seconds)	Average (variation) of time to ignition (seconds)
Green	29.37	42.18	35.3 (4.1)
Attacked	15.14	27.1	20.7 (3.9)
Yellow	10.69	29.75	16.6 (5.6)
Red	11.2	14.99	13.3 (1.2)

# MOISTURE CONTENT, FIBER CARBOHYDRATES AND FATS WERE ALL SIGNIFICANT FACTORS TO FOLIAGE IGNITABILITY



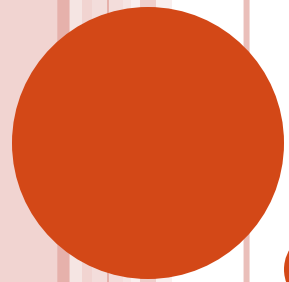


# MOISTURE CONTENT, AMOUNT OF FAT AND FIBER EXPLAIN MOST OF THE VARIATION IN IGNITION TIMES



- Increasing moisture contents increases time to ignition
- Increasing fiber or fats decreases time to ignition





# FROM NEEDLES TO TREES

# ROCKY MOUNTAIN NATIONAL PARK SINGLE TREE TORCHING EXPERIMENTS

**Impacts of Mountain Pine Beetle on Lodgepole Pine Fire Behavior**  
Rocky Mountain National Park, Colorado

Nate Williamson, Mike Lewelling – Rocky Mountain National Park  
Monique Rocca, Bill Romme – Colorado State University

**Background**

Mountain pine beetle (*Dendroctonus ponderosae*) populations have reached epidemic levels throughout the western U.S. and Canada. Although the pine beetle is a native insect, population levels currently being observed are without precedent in recorded history. The resultant tree mortality will affect future stand structure and composition and fuel dynamics in our forests for decades to come. There is considerable uncertainty as to how the current epidemic will affect future fire behavior in beetle-killed stands.

Following attack by the beetle, the impacted trees are killed and the needles subsequently die and dry out. These red needles will remain on the tree for 2-3 years before falling to the forest floor. It is thought that the risk of a crown fire may be greater in stands composed primarily of standing dead trees with red needles than stands of green trees. A prescribed burn project was conducted at Rocky Mountain National Park to investigate the flammability of lodgepole pine crowns as well as the mechanisms of pine seed dispersal following beetle attack.

**Lodgepole Pine Mortality Due to Mountain Pine Beetle (in orange) 2001 - 2008**

**Questions**

What impacts will the beetle have on fire behavior in lodgepole pine?  
Will crown fire risk be greater in beetle-killed stands?  
Can we use prescribed fire to shorten the "red needle" stage?  
Does crown flammability change with time since beetle attack?

**Preliminary Results and Discussion**

Under typical late winter/early spring conditions, green healthy crowns not receptive to fire.  
Green beetle-killed crowns no more receptive to fire than green, healthy crowns under project conditions.  
Red needles crowns more receptive to fire, however period of increased risk only about 2 years.  
Following loss of 20% of needles, lowered crown bulk density limits fire spread to beetle killing stage.  
Increased fire risk due to beetles may be exaggerated. Red needles may be more receptive to fire, however period of increased risk is short-lived.  
Lodgepole pine is a fire-adapted species, there will always be a risk of high intensity fire with or without mountain pine beetle.

**Crown Torching Pilot Project**

**Objectives:**  
Investigate flammability of beetle-killed lodgepole pine crowns relative to non-affected trees  
Determine feasibility of using fire to reduce canopy fuels

**Methods**

Identify trees in various stages of time since beetle attack:

- Unattacked: green needles
- Attacked previous summer: all green
- Attacked 1 year ago: mixed red and green needles
- Attacked 2 years ago: 80-100% red needles remaining
- Attacked 3 years ago: 60-79% red needles remaining
- Attacked 4 years ago: all red needles and conifer

**Perception**

Beetle-killed stands at greater risk to high

Lodgepole Crown Status	Number of trees	% of crown that carried fire
alive, not attacked	5	0%
attacked, still green	3	0%
mixed red and green needles	1	100%
80-100% needles remaining	3	100%
60-79% needles remaining	2	50%
40-59% needles remaining	3	0%



**Green tree, unattacked**



**Red tree, attacked 2 years ago**



**Red tree, attacked 3+ years ago**

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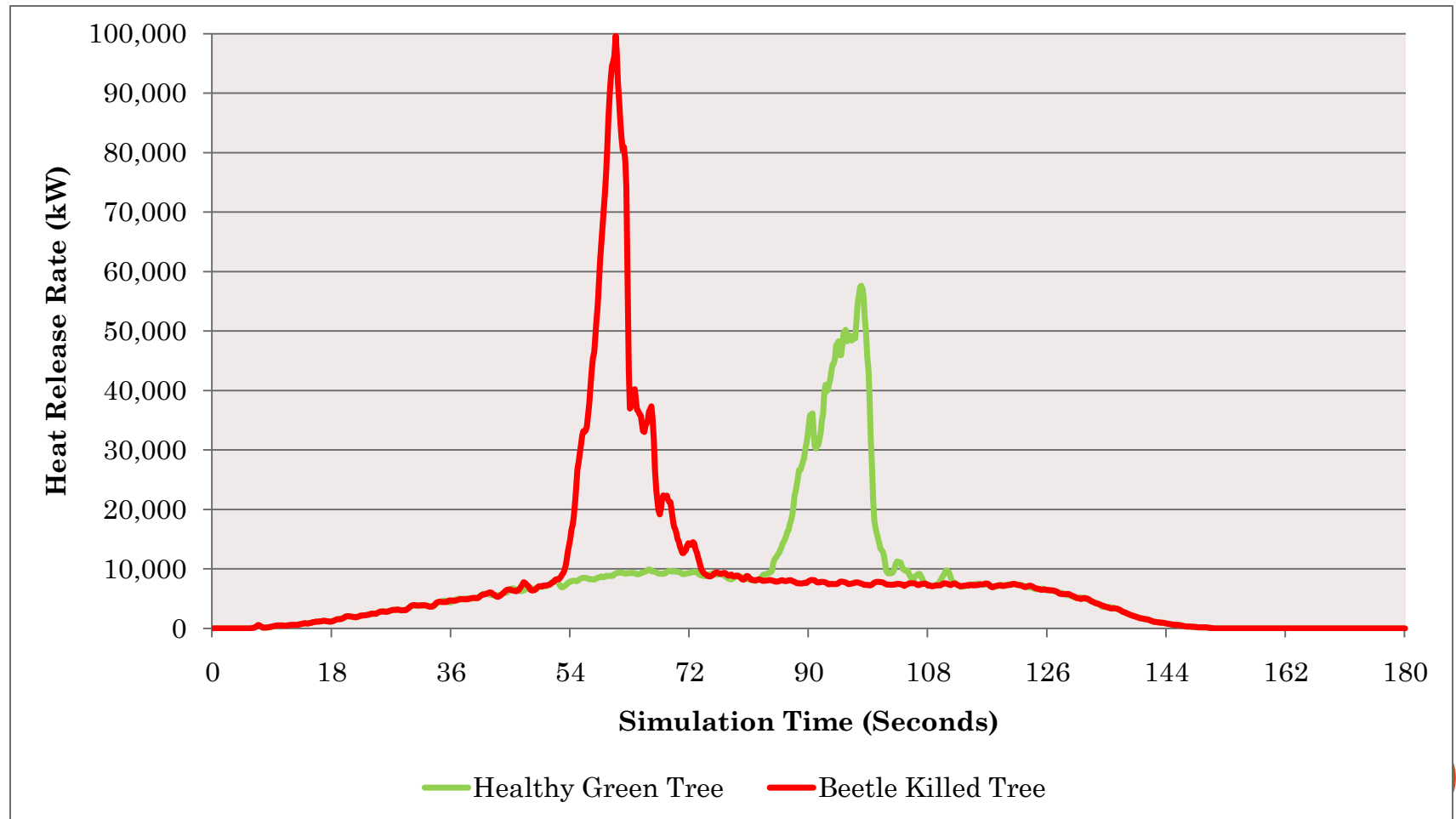
# **SIMULATING FIRE BEHAVIOR IN BEETLE-ATTACKED TREES**

# THREE DIMENSIONAL FIRE BEHAVIOR MODELING OF BETTLE-KILLED TREES USING THE FIRE DYNAMICS SIMULATOR

Insert Video #1



# HEAT RELEASE RATE OF RED NEEDLE AND HEALTHY GREEN TREES



# TAKE HOME POINTS

- Red needles are about ten times drier than green needles
  - Attacked trees can show moisture content and chemical changes before color change occurs
- Red needles ignite about three times faster than green needles
  - In the absence of structural changes, less heat is required to ignite the crowns from either below or above
- Increasing needle fiber or fat content will also increase flammability
- Red needle trees release more heat, faster and this may lead to increase spotting distance
- The structural changes of the fuels with time since attack have still not been completely described



# WHAT DOES THIS ALL MEAN TO FIRE BEHAVIOR?

- Longer spotting distances
  - Spot fires up to a  $\frac{1}{4}$  mile from a single torching tree have been observed in red needle trees and  $\frac{1}{2}$  mile from grey stage trees.
- Higher probability of ignition
  - More receptive fuels ahead of the approaching fire
- Larger safety zones required due to a larger potential net heat release.

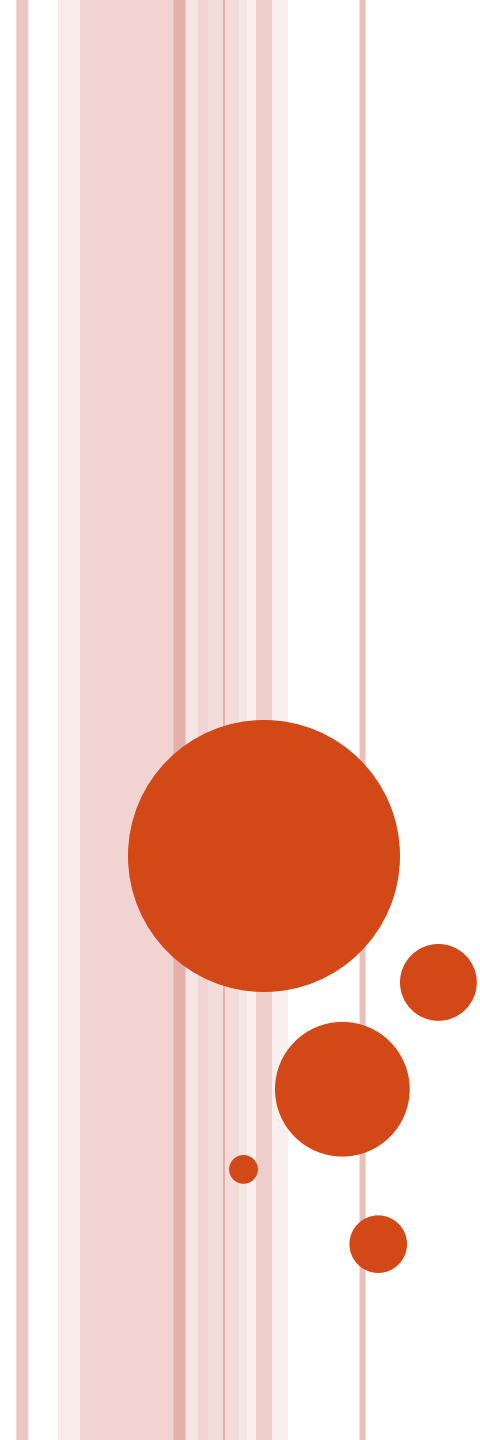




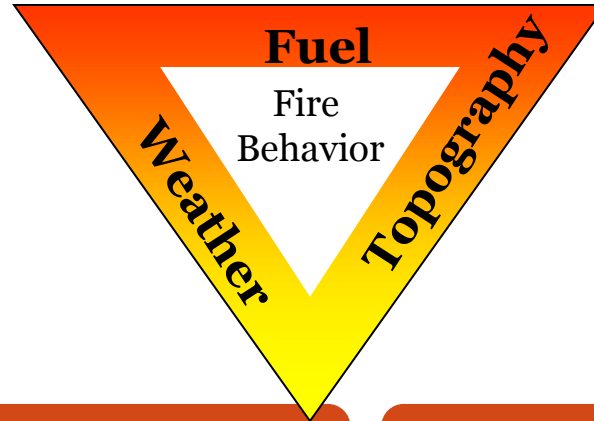


Mike Pritchard, BC Wildfire Mgt Br.

Fire number G40376, July 3rd, 2006  
23 hectares

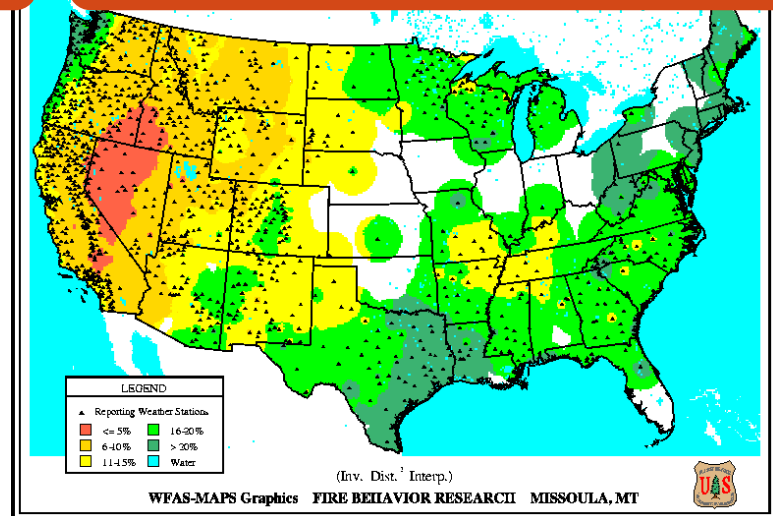
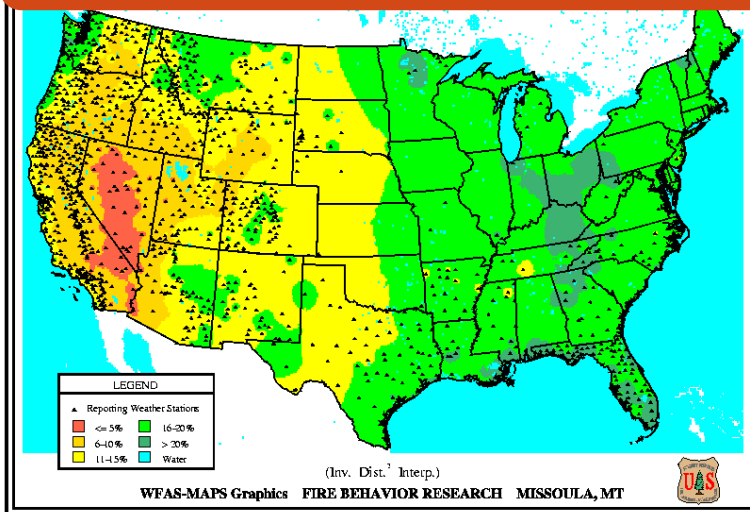


**ONE LAST THOUGHT:  
IF THE FOLIAGE IS SO FLAMMABLE,  
WHY HASN'T IT BURNED YET?**



## Heavy dead fuel moistures in 2010

## Heavy Dead Fuel Moistures in 2007



- Weather has been a significant factor in reducing fire potential in Montana over the last few years.
- Changes in the fuel structure over time are also important but not well understood

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**THANK YOU AND  
QUESTIONS?**